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AERIAL PHOTOGRAPHIC CENSUS OF CALIFORNIA SEA LION *(Zalophus californianus)* PUPS AT SAN MIGUEL ISLAND, CALIFORNIA FOR 1987-1990 AND SAN NICOLAS ISLAND, CALIFORNIA FOR 1990

By

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Aerial photographic census of California sea lion (*Zalophus californianus*) pups at San Miguel Island, California for 1987-1990 and San Nicolas Island, California for 1990

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INTRODUCTION

In the United States, California sea lions (Zalophus californianus) breed off the coast of southern California at San Miguel (SMI), San Nicolas (SNI), San Clemente and Santa Barbara Islands (DeMaster et al. 1982, Stewart and Yochem 1984, Oliver and Lowry 1987, Lowry et al. 1987). Pup counts taken during the June-July breeding season are used to determine the status of the United States population (DeMaster et al. 1982, Boveng et al. 1988). Previously, California sea lion pups have been counted on the ground and from aerial photographs taken with 35 mm, 101 mm X 127 mm, and 228 mm format cameras (Bartholomew and Boolootian 1960, Odell 1971, Mate 1977, Stewart and Yochem 1984, Oliver and Lowry 1987, Lowry et al. 1987). In this paper we introduce equipment and procedures we use to count California sea lion pups from large-format (126 mm) vertical photographs and present pup counts for SMI and SNI (Figure 1).

METHODS

After testing other camera formats (35 mm, 70 mm, and 228 mm) we chose the 126 mm (five-inch) format KA-45A camera, equipped with forward motion compensation (FIMC), to collect the aerial photographs for counting California sea lion pups. The camera was set for 66% overlap between adjacent frames for the

majority of photo passes, and at 75% overlap on passes over areas where large concentrations of sea lion pups are known to occur. Kodak Aerochrome 2448 color transparency film was used. We exposed the film for normal contrast on sandy areas and overexposed by one half to one f-stop for rocky substrate. The camera was set at apertures of f/4 or f/5.6 and shutter speeds between 1/400 and 1/1500 sec.

The camera was mounted vertically in a twin-engine Partenavia P-68 aircraft. Photographs were taken at an altitude between 183 m and 259 m (600-850 feet) and at an airspeed of approximately 110 kts. Ground speed, for setting the FIMC, was calculated by converting sea state to wind speed with the Beaufort scale and adding that value to the airspeed during tail wind conditions or subtracting it from the airspeed during head wind conditions. Environmental conditions, such as wind velocity, sky condition, and cloud ceiling, were noted during each flight. The aircraft altimeter was used to determine cloud ceiling. Tidal height during the flight was interpolated from tide tables (Anonymous 1986, 1987, 1988, 1989).

Photographic censuses were conducted twice in 1987 and 1990, and once during 1988 and 1989 (Table 1). Two missions were flown in 1987 to evaluate peak breeding season (28 June) and late breeding season (26 July) pup counts. The flights made in 1988 and 1989 were made during late breeding season (17 July and 26

July, respectively). Two late season flights in 1990 were made on 18 July and 25 July to investigate variability in pup counts between aerial photographic flights.

We photographed the sea lion hauling areas along the coastline of SMI and SNI, and the entire surface area of Point Bennett and Castle Rock at SMI (Figures 2 and 3). Most flights were made around noon to minimize shadows.

California sea lion pups were counted with a Hoppman viewer enlarger, set at a magnification of 19X. This viewing system projects an image onto a 35 cm X 35 cm frosted glass screen. To prevent double counting of pups, clear acetate plastic squares were anchored over selected photographs to divide the rookery into smaller counting zones before the photograph was magnified with the viewer. A clear piece of 0.007 mm or 0.013 mm thick mylar plastic was anchored with tape over the glass screen of the viewer. Pups were marked with a pen on the mylar as each individual was counted.

We divided the rookeries and hauling grounds into counting areas as shown in Figures 2 and 3. At SMI natural breaks in aggregations or geography were used to delineate the areas, whereas at SNI we used the Bureau of Land Management (BLM) area code system used by Bonell et al. (1980).

Replicate counts were made of sea lion pups photographed on sandy substrate and rocky substrate. Three counts were made of the same counting zones by photo-interpreter 1 (MSL) and one count was made by photo-interpreter 2 (WFP). We used coefficient of variation analysis (Program Statview, Macintosh) as an indicator of count precision.

RESULTS

The KA-45A camera with forward image motion compensation produced photographs with better resolution than the small format (35 mm), medium format (70 mm), and large format (228 mm) cameras we tested prior to our surveys. This camera produced photographs of excellent quality for counting sea lion pups. At an aperture setting of f/4.0, our resolution with Kodak 2448 color film was 27 to 32 line pairs per mm, which was improved to 35+ line pairs per mm when we switched to f/5.6 (Morgan Lynn pers. comm. February 1991). The rapid cycling capability of the camera increased our overlap between adjacent frames, giving us 3 or 4 photographs of each area (from slightly different perspectives).

California sea lion pup census

Counts of California sea lion pups at SMI were stable during

the four years of the survey. They ranged from a low of 11,055 in 1988 to a high of 12,807 in 1987 (Table 2). Northwest Point (Area C) produced the highest pup counts each year, accounting for 29 to 38 percent of the total.

At SNI we counted 11,766 sea lion pups in July 1990 (Table 3). BLM area 230 produced the highest pup counts, accounting for 45 percent of the total.

Replicate flights

The counts obtained for the replicate flights in 1987 and 1990 were similar (Tables 2 and 3). At SMI, the first flight's count was 5.1% lower in 1987 and 10.3% higher in 1990. At SNI, the first flight's count was 9.2% lower in 1990.

Replicate counts

Replicate counts of sea lion pups by one interpreter corresponded closely for sand (Coefficient of Variation [CV] = 0.0140) and for rock substrate (CV = 0.0277; Figure 4). Pup counts by two interpreters corresponded closely for sand substrate (CV = 0.0195), but increased for rock substrate (CV = 0.0905; Figure 4).

DISCUSSION

California sea lion pup counts at SMI have risen 29% from the 9,279 pups reported for 1980 (DeMaster et al. 1982). During the four years of our surveys, pup counts at SMI remained fairly stable at about 12,000 animals. The distribution of pups shifted during our surveys; decreasing at Northwest Point (Area C) and increasing at Pt. Bennett, South Cove, and the southern shoreline (areas E, G, and J, respectively).

The 1990 sea lion pup count at SNI is up by 42% from the count of 7,738 reported for 1982 (Stewart and Yochem 1984). The rookery is expanding, with a new pupping area located in BLM area 265. In 1990, pup production at SNI was almost the same as at SMI (11,766 and 12,203, respectively).

The results of the replicate counts by two photo-interpreters demonstrate how rookery substrate affects the precision of sea lion pup counts. Pups counted on sand are very similar for two interpreters (CV = 0.019) because of the sharp contrast between pups and the light sandy background. Pups counted on rocky substrate are still very precise by a single interpreter (CV = 0.028), but precision and accuracy are confused when a second interpreter is added (CV = 0.090). Counting pups on rocky substrate requires more subjective decisions because of the subtle difference in contrast between pups and their

background.

Replicate flights indicate that the precision of pup counts is improved by sampling during conditions that promote movement of pups into substrate and areas that expose them to vertical photography. The higher pup counts at SMI occurred on clear days with 11-16 kt winds; whereas the higher pup count at SNI occurred during high tidal conditions (1+ meters) with the tide height being 0.3m (1 foot) higher than the previous flight, resulting in fewer low lying areas being exposed. At SMI, clear days with strong winds (11 kts or more) provide good lighting conditions for photography and the cool ocean breeze keeps pups away from shady areas or tide pools where they will be hidden from the view of the camera. At SNI, high tides (1+ meters) flood areas frequented by pups and forces them to exposed areas and on substrate where they can be photographed. If these guidelines are followed, we believe that they would reduce the 5% to 10% difference (or error) we found between replicate flights and obtain a count that is very close to the number of animals present. Because it may not always be possible to conduct photographic censuses when these optimum environmental conditions occur, the variance associated with counts obtained for each environmental condition or combinations of conditions needs to be determined.

The rookeries at SMI and SNI are ideal for low-altitude

vertical photography because there are no overhanging high cliffs and the substrate (sandy beaches or brown sandstone) provides excellent contrast for detecting pups. The rookeries at Santa Barbara Island and San Clemente Island do not meet these conditions, so they must be censused using conventional ground census techniques. Additional benefits to using vertical imagery to census sea lion pups is that the technique minimizes disturbance to the rookeries. Further, the photographs can be used to accurately determine the areas occupied by animals, sizes and spacing patterns of animals and provide a permanent record of the rookeries and surrounding habitat for future study.

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Table 1. Environmental conditions at San Miguel Island (SMI) and San Nicolas Island (SNI) during aerial photographic censuses of California sea lion pups from 1987 through 1990.

Flight Date	Island	Local time	Wind velocity (kts)	Sky condition	Fog ceiling (meters)	Tide height (ft)
28 June 1987	SMI	1300-1425	4-10	fog/hazy	366	0.8-1.0
26 July 1987	SMI	1145-1320	11-16	clear	-	2.9-3.6
24 July 1988	SMI	1320-1430	?	fog	244	3.8-4.3
21 July 1989	SMI	1310-1420	11-21	clear/hazy	-	3.3-4.1
18 July 1990	SNI	1210-1250	11-16	clear	-	2.4-2.6
	SMI	1320-1505	11-16	clear	-	2.9-4.3
25 July 1990	SNI	1415-1425	4-6	clear	-	3.5-
	SNI	1425-1445	4-6	thin fog	366	-3.7
	SMI	1500-1630	5-7	clear	-	2.5-3.2

Table 2. Counts of California sea lion pups made from vertical aerial photographs taken at San Miguel Island, California.

Area	Area code	Dates of California sea lion pup census flights					
		June 28 1987	July 26 1987	July 24 1988	July 21 1989	July 18 1990	July 25 1990
Northeast Pt. to East Rocks	A	192	172	114	153	82	85
Northeast Pt.	B	725	773	668	903	492	578
Northwest Pt.	C	4,594	4,862	3,826	4,338	3,615	2,903
Northwest Pt. Rocks	D	33	139	67	94	64	50
Point Bennett	E	2,002	2,037	1,720	1,905	2,623	2,016
Point Bennett West Rock	F	24	42	39	46	26	22
South Cove	G	2,596	2,330	2,415	2,787	2,753	2,762
Cormorant Rock	H	253	350	269	317	265	245
Adams Cove	I	667	823	635	680	791	876
Little Cove to Tyler Bight	J	705	849	930	1,128	1,261	1,312
Castle Rock	K	361	430	372	349	231	217
Total		12,152	12,807	11,055	12,700	12,203	11,066

Table 3. Counts of California sea lion pups made from vertical aerial photographs taken at San Nicolas Island, California.

BLM area code	18 July 1990	25 July 1990
210	361	461
220	514	916
230	4,826	5,282
240	3,599	3,768
260	1,340	1,309
265	43	30
Total	10,683	11,766

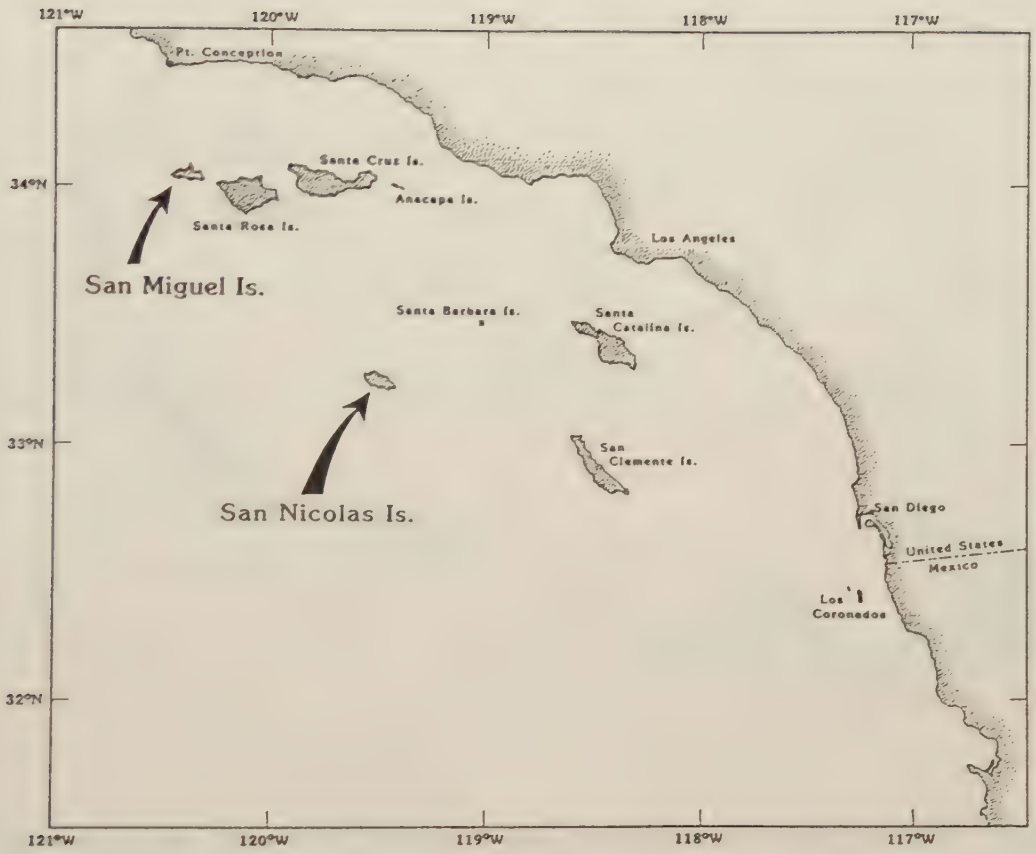

Figure 1. Map showing location of San Miguel Island and San Nicolas Island.

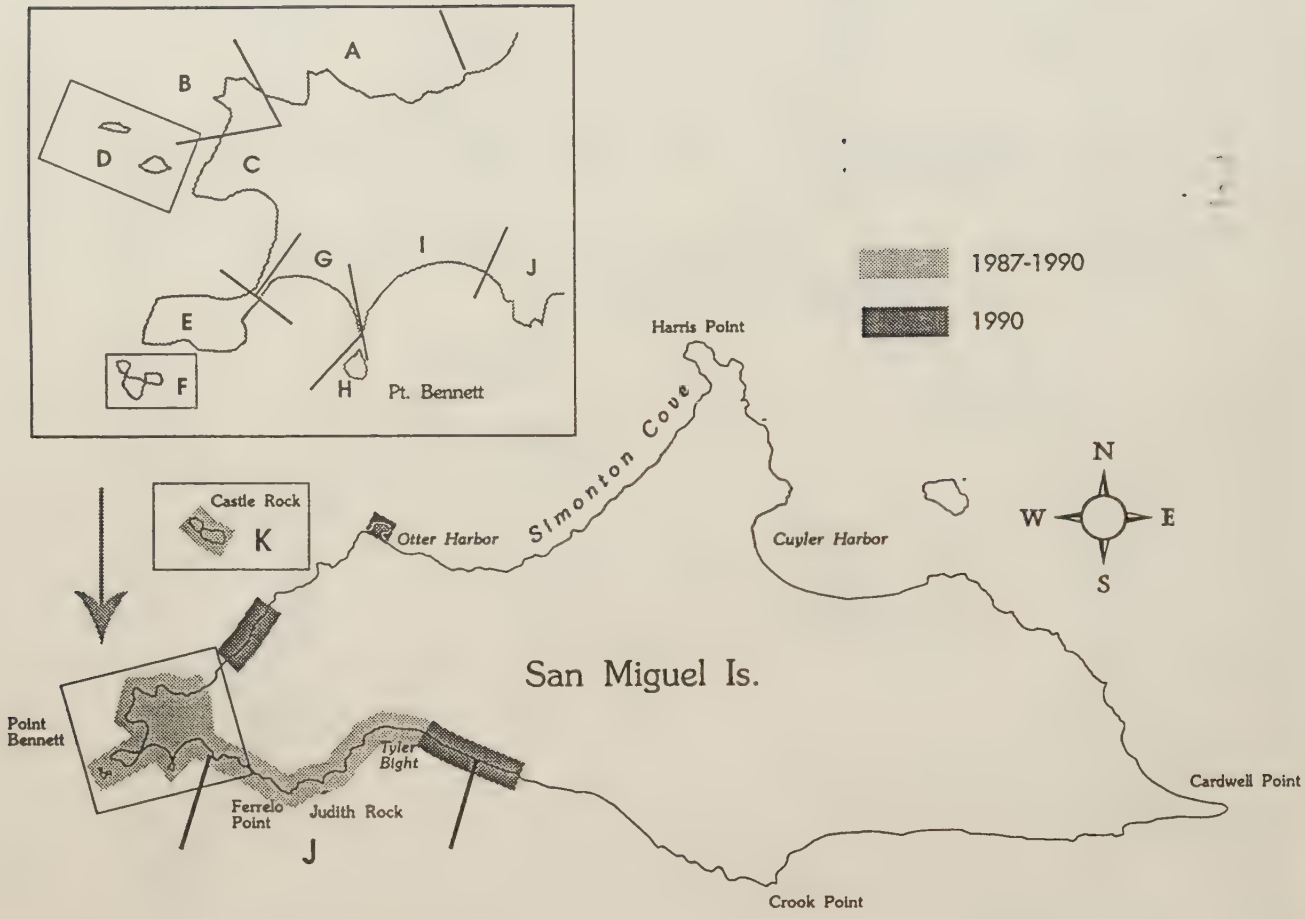

Figure 2. Map of San Miguel Island showing shaded areas where California sea lions were photographed with 126mm format aerial color photographs and area codes for pup counts (inset is map of Point Bennett hauling grounds).

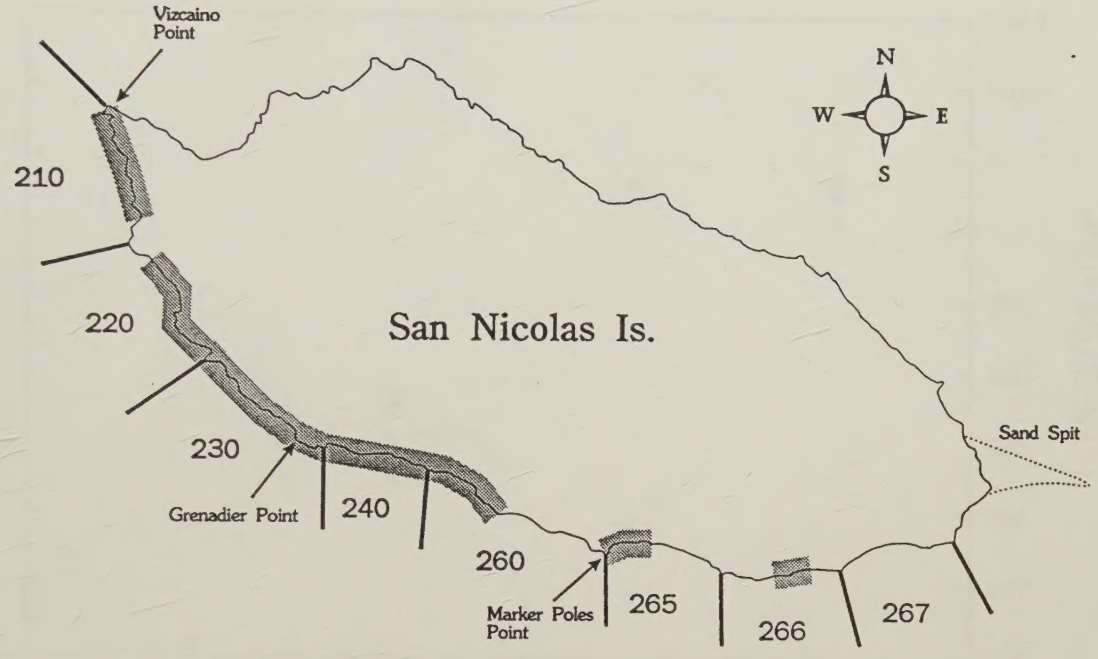

Figure 3. Map of San Nicolas Island showing shaded areas where California sea lions were photographed with 126mm format aerial color photographs and Bureau of Land Management (BLM) area codes.

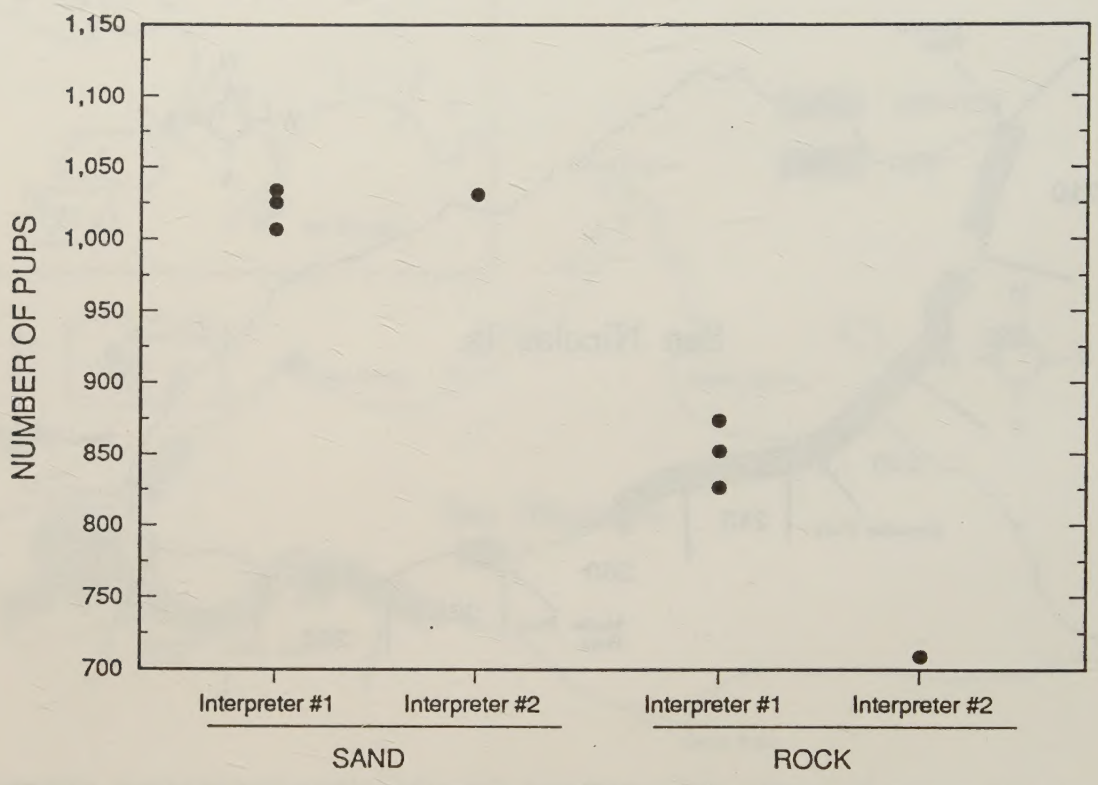

Figure 4. Replicate counts of California sea lion pups made by two interpreters of pups on sandy substrate and pups on rocky substrate. Interpreter 1 made three counts and Interpreter 2 made one count.